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Technology Neutrality for Sustainable Transport

Critical Assessment of a Postulate – Summary

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Imprint

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Preface

Recent calls for technology neutrality have generated lively and controversial debates. But the discussions have also been characterised by conceptual vagueness. Many commentators use technology neutrality synonymously with the term technology openness. Others use these terms as a means to uphold the existing system. The lack of conceptual precision has spilled over into discussions about sustainable transport. Buzzwords have taken the place of arguments.

The purpose of this study is to provide basic conceptual clarity. Moreover, we want to supply the rational foundations for central policy decisions. In particular, we answer the question: Which regulation can ensure that the transition from internal combustion engines to low-emission drive trains and energy sources succeeds as cost-efficiently as possible?

The following study is no easy read. But it is nevertheless important. It takes an objective approach to discussions of technology neutrality and sustainable transport, creating the kind of solid foundation that expedient policy needs. And with the transition to sustainable transport set to begin in earnest, such policy is more urgent than ever.

Christian Hochfeld
Agora Verkehrswende
Berlin, 22 January 2020

Key findings

1. Technology openness is a prerequisite for a successful and cost-efficient achievement of a sustainable transport sector. This means switching to new drive trains and fuels in an undistorted competitive field factoring in all economic costs and benefits of the various technologies.

2. Technology openness does not mean technology neutrality. Technology-neutral regulations do not discriminate against available technologies. They generate technology openness only when technologies compete against each other under undistorted conditions. However, in practice technology-specific regulations are needed as well to overcome path dependencies in the transport sector and to guarantee technology openness.

3. Technologies that harm the climate must be curbed to make space for new climate friendly ones. Path dependencies and external costs bias technology competition towards combustion engines and fossil fuels. A key approach for correcting these distortions and supporting the market exit (exnovation) of fossil fuels is an effective carbon pricing. Other supplementary instruments are a carbon-based vehicle tax and strict fleet-wide emission limits for new cars.

4. Technology-specific policies are needed to promote infrastructure for new drive systems. To find acceptance, drive systems require a sufficiently tight-knit and user-friendly energy supply infrastructure network. But the private sector can profitably build infrastructure only when the technology is widely used. Accordingly, the state should temporarily promote the expansion of infrastructure and create a regulatory framework that enables the simple usage of this infrastructure.

5. Support new technologies' competitiveness. In order to overcome remaining barriers, targeted and temporarily limited support programmes can facilitate the market entry and ramp-up of innovative technologies. The programmes should consider the state of development of technologies and their projected contribution to decarbonisation. Moreover, it seems desirable that the necessary financial means are raised in the transport sector itself, e.g., by the means of a bonus-malus system.

6. Generate investment security by a long-term political commitment to sustainable transport and ambitious policy measures. Effective political commitment requires setting and achieving explicit sector targets. Moreover, the state should signal the inevitability of a transition towards a sustainable transport system by making targeted public investments and enacting a broad instrument mix for the reliable achievement of the transport sector emission target. Furthermore, it must seek to build the broadest political consensus possible.

Content

Sustainable transport and technology neutrality

The climate bill that Germany passed in December 2019 sets yearly limits to the amount of greenhouse gas emissions that each of its economic sectors may release over the next decade. The limit for the transport sector in 2030 is 95 million tonnes of CO_2 equivalents.[1] This represents a reduction of 42 % relative to 1990 levels, and the upper target defined in Germany's 2050 Climate Action Plan.[2] The targets in the 2019 bill serve to meet Germany's commitments at the European level while setting a course to reach greenhouse gas neutrality at the national level by 2050.

If Germany is to achieve its climate policy goals in the transport sector, it will need to bring about a fundamental transformation towards sustainability. Sustainable transport rests on two pillars: mobility transition and an energy transition.[3] The first pillar consists in the reduction of traffic volume, a switch to more environmentally friendly modes of transport (e. g. public passenger transit and rail freight), the use of intermodal travel, and the creation of a more energy-efficient and effective transport system. The second pillar involves a transition to low- or zero-emission drive trains and energy sources. This report focusses primarily on how this second pillar should be addressed in regulation. There is broad agreement that an energy transition must take place in the transport sector. But German policymakers and stakeholders are at odds about which policies and regulations are needed to bring clean energy to the transport sector and to achieve the country's medium- and long-term climate targets as efficiently as possible.

A central topic of recent policy discussions has been "technology neutrality," the principle that climate policies must treat all technologies for eliminating greenhouse gas emissions equally. Supporters of technology neutrality argue that governments should introduce measures that incentivise greenhouse gas emission reductions without differentiating between technologies capable to do so, e. g., by the means of a uniform carbon price. Decisions about which technology to use should be left to private actors, which are better positioned to understand the costs and benefits of each option. According to its backers, a technology-neutral climate policy leverages the decentralized knowledge of the market, thus creating an undistorted competitive environment in which the most efficient technologies win out. Hence, they maintain, only technology-neutral policy instruments will allow to achieve the climate targets as cost-effectively as possible (efficiency thesis).

There is much debate whether strict technology neutrality is the best way to advance clean energy and quickly bring it to the transport sector. At the beginning of 2019, Volkswagen CEO Herbert Diess called for the state to promote the purchase of battery-electric cars because electric drive trains had already won the "technology race".[4] His statement met with much criticism, some from within the automotive sector itself. The German Association of the Automotive Industry responded by saying that the creation of a sustainable transport sector "will be successful in the long run only if the best and most appropriate solutions prevail in technology-neutral competition".[5] Germany's federal government, for its part, appears divided, with some ministries attaching more importance to technology neutrality, and some more importance to technology-specific approaches. A similar ambivalence can be found in German climate policies to date.

1 See the Gesetz zur Einführung eines Bundes-Klimaschutzgesetzes und zur Änderung weiterer Vorschriften from 12 December 2019, BGBl. 2019, part 1 no. 48, 2513 – 2521.

2 See Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU) (2016). "Klimaschutzplan 2050 – Klimaschutzpolitische Grundsätze und Ziele der Bundesregierung," Berlin.

3 See Agora Verkehrswende (2017). "Mit der Verkehrswende die Mobilität von morgen sichern – 12 Thesen zur Verkehrswende," Berlin.

4 "Flucht nach vorn," Der Spiegel, no. 8, 16.02.2019, p. 62.

5 See Verband der deutschen Automobilindustrie (2019). "Mobilität und Wachstum in Europa Empfehlungen der deutschen Automobilindustrie für die 9. Legislaturperiode des Europäischen Parlaments," Berlin.

Objective and scope

In view of the ongoing debate on technology neutrality among researchers and policymakers, we address the following central question:

> Which policy priority – technology neutrality, technology specificity, or a combination of the two – is the most cost-effective way of bringing about an energy transition in the transport sector?

In particular, we look critically at the economic arguments for and against each of these options. First, however, we define the key concepts and clarify some ambiguities – such as the synonymous use of the terms "technology neutrality" (Technologieneutralität) and "technology openness" (Technologieoffenheit) in public discussions in Germany.

After defining the key concepts, we focus on regulatory policies shaping drive technologies and energy sources for German road transport, with special emphasis on passenger cars, trucks for local deliveries and long-distance haulage. Our discussion of climate and technology policies is mainly carried out against the background of Germany's 2030 climate targets for its transport sector but also takes into account its overall goal of decarbonising the sector by 2050. Of course, such long-term perspective is always accompanied by significant uncertainties and challenges; technological developments in particular are very hard to gauge. Accordingly, it seems very likely that Germany will have to realign its policy instruments after 2030 and possibly earlier in order to reach its long-term climate targets in a cost-effective manner.

Definitions of key concepts

When it comes to the decarbonisation of road transport, there's no way around state intervention. The reason is that market prices do not reflect the climate impacts of using fossil fuels and other externalities such as the harm caused by emitting air pollutants. The question that needs answering is whether, from an economic standpoint, state interventions should remain neutral vis-à-vis the various competing technologies that exist for low- and zero-emission mobility.

Technology neutrality of regulation consists of two dimensions. First, a perfectly neutral regulation intervenes directly at the level of the predefined policy objective (such as the reduction of greenhouse gas emissions). In doing so, it grants as much leeway as possible on subsequent levels (e.g., in the individual sectors) and abstains from further downstream climate regulations such as separate targets for the electricity, heat and transport sector (or even for road, rail and air transport within the transport sector). Second, it does not discriminate among individual technologies. Instead, it leaves the choice between technologies to private actors. The assumption is that these actors have a better understanding of the costs and benefits of the various technology options, and that decentralised market-based decisions without state interventions yield a social cost optimum. The more a real-world regulatory design deviates from these prerequisites for perfect technology neutrality, the more it becomes technology-specific.

But regulations are rarely purely technology-specific or purely technology-neutral. Instead of being two dichotomous alternatives, technology neutrality and technology specificity are the opposing poles of a complex two-dimensional continuum in which concrete regulations arise. For instance, an emissions trading system restricted to specific sectors automatically rules out certain technologies for reducing greenhouse gases, and thus contains a technology-specific element. In other words, real-life climate regulations never come down to either-or choices. They are complex undertakings that must find an appropriate balance of both principles.

It is important to distinguish technology neutrality from a term with which it is often used interchangeably in German debates: technology openness. Technology openness describes a regulatory environment along with its decisionmakers, technologies, markets, and existing regulations. Technology neutrality, by contrast, describes a particular state intervention. A decision space is "technology-open" if the choice of technology is undistorted apart from the distortion to be corrected for (i. e. the external costs of greenhouse gas emissions). A decision space is undistorted when its (private or public) decision-makers take into account all the socially pertinent costs and benefits.

Technology neutrality does not always guarantee technology openness

If further market imperfections exist besides the external costs of greenhouse gas emissions, or if the policy decision is not only motivated by social welfare, the decision space is distorted. The reasons for a lack of technology openness are manifold. (For a list, see Box 1.) Technology-neutral policies for mitigating climate change can ensure the achievement of the decarbonisation target at minimal social costs only if they encounter a decision space that is perfectly technology-open. In real-life climate politics, decision spaces are typically biased, however. That is to say, technology-neutral regulations by themselves do not engender technology openness. To correct existing biases, the state must introduce technology-specific regulations. Technology specificity may also be needed if the regulation pursues other goals in addition to decarbonisation – see again Box 1 – or if the assumption that distributed private actors have better information than a central regulator proves false.

Regulation to mitigate climate change may be efficient while being technology specific, or efficient while being technology neutral, depending on the decision space, as Fig. 1 shows. If the decision space is assumed to be persistently biased towards a technology, one must rule out policies that are strictly technology-neutral, because they will perpetuate existing distortions and will be unable to guarantee the most cost-efficient approach to achieving the policy goal.

Technology-specific regulations do also have risks, however. While in theory a well-designed technology-specific regulation can be efficient, a poorly designed regulation may not be, as Fig. 1 shows. The requirements for a technology-specific regulation to be efficient are high. Regulators must possess information about the existence and scope of biases in the decision space if they are to design corrective technology-specific instruments. In addition, the design of the regulation may not be biased as a result of political self-interest or the influence of interest or pressure groups. Past experiences show that technology-specific regulations frequently do not satisfy both requirements. For instance, the German Renewable Energy Sources Act (EEG) contains politically distorted discriminations and adjustments within its technology-specific feed-in tariffs for renewable energies. So with the indication for technology-specific regulation (question of indication) comes the challenge of determining the proper form of technology specificity for the existing decision space (question of adequacy).

Technological neutrality and technological openness

Figure 1

Regulation	Decision space: Low technological openness before regulation	Decision space: High technological openness before regulation
technology-neutral	inefficiently neutral	efficiently neutral
technology-specific	efficiently discriminatory / inefficiently discriminatory	inefficiently discriminatory

Authors' depiction

Box 1

Economic indications for technology-specific regulations

Technology-specific regulations can be indicated on cost-effectiveness grounds in the following situations:

1. **The technology openness of the decision space is limited. This could be because of**

   … dysfunctional market coordination (i.e. the existence of market imperfections) due to, e.g.,
   - knowledge spillovers, i.e. societal benefits from new technological knowledge ignored in private investment decisions
   - market power in technology, commodity and service markets
   - information deficits and asymmetries among consumers regarding technology features
   - behaviourial consumer-side barriers (focus on the present, perceptions of new technologies)
   - consumer-side budget restrictions (limited available income for the purchase of new cars, imperfect credit markets)

   … private technology decisions being distorted by the policy sphere (policy failure) due to, e.g.,
   - imperfect regulations (e.g., insufficiently high carbon prices)
   - policy uncertainties (e.g., frequent changes to policy framework)

   … insufficient dynamic adaptability of technological systems (path dependencies), due to, e.g.,
   - technological path dependencies (complementary energy supply infrastructure, network and learning effects, economies of scope, sunk costs)
   - institutional path dependencies (design of the regulatory framework, mental models, i.e., conventional ideas about how to organise the transport system)

2. **Other regulatory objectives exist in addition to decarbonisation, e.g.**
   - further environmental objectives
   - distributional objectives
   - industry policy objectives

3. **Regulators are equally well informed as private actors, especially with regard to**
   - the private costs and benefits of available technologies (including the non-monetary costs, e.g., use restrictions because of limited vehicle range)
   - future private costs and benefits of available technologies and knowledge of new technologies

The relevant question for regulatory practice is not, therefore, whether to endorse or reject technology neutrality. Rather, the question is the appropriate level of technology specificity and the concrete design of the instrument mix.

All things considered, the potential cost-effectiveness of a technology-neutral intervention increases

- the greater the technology openness of the decision space is before the government intervention;
- the less the regulation aims to address additional objectives beyond decarbonisation; and
- the less government regulators have access to information needed for cost-effective technology-specific policies.

The inverse conditions apply for the cost-effectiveness of technology-specific interventions. Typically, a mix of technology-specific and technology-neutral approaches produces the most cost-effective solution. Hence the task is not to choose between these approaches but to find an appropriate solution in a complicated decision space shaped by a variety of biases.

Technology-specific policies are indicated for road transport

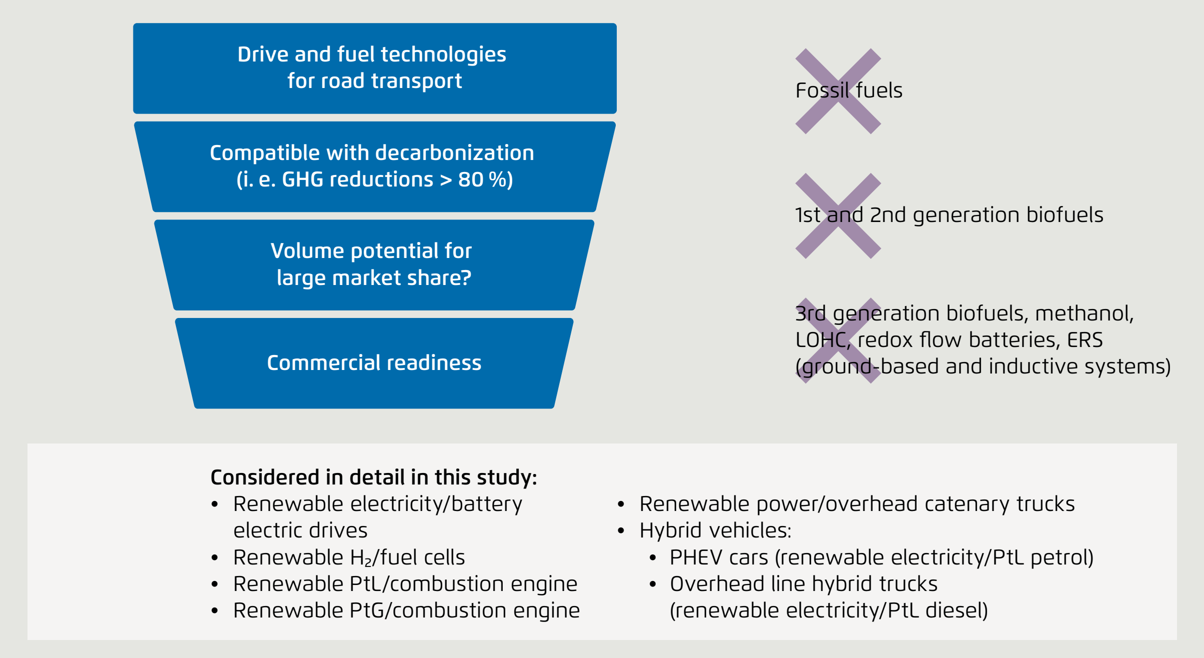
Whether technology specificity is indicated for road transport policies depends on a number of questions:

- Is the technology openness of the decision space limited?
- What are the policy aims connected with the energy transition in the transport sector?
- Do central policy decision-makers possess sufficient knowledge about the features of the decision space?

To answer these questions, we classified selected technologies with regard to the economic indication of technology-specific interventions. We broke down the three economic indications for technology specificity described in Box 1 into 29 separate factors. We then analysed technologie for three decision spaces in road transport – passengers cars, light trucks for local deliveries, and trucks for long-distance haulage –that promise to make a significant contribution to achieving Germany's 2030 climate target. (See the light grey box in Fig. 2.). Below are our main findings:

Summary of the technology selected for the present study

Figure 2



Authors' depiction

The technologies needed to reduce greenhouse gas emissions in the area of road transport by 2030 are largely known today. This means that the basic information required for the state to intervene in private technology selection is available. It can be expected that the road transport sector will require a diverse portfolio of technologies to reduce its greenhouse gas emissions (cf. Box 2 and Fig. 3). Battery-electric drive trains will play a major role in passenger cars and light utility trucks for local deliveries. Long-haul trucks could use a mix of fuel cells, battery-electric drive trains, and electric road systems (using e.g. overhead catenary lines for electricity supply while the vehicles are in motion). What is needed is a regulatory framework that enables the right mix of technologies. But there are still many unknowns. It can't be predicted with certainty what the most cost-effective technology mix for 2030 will be. Accordingly, state regulation stipulating a certain share or even the exclusive use of specific technologies carries risks. Likewise, the details of the technology options – e. g., the type of technology for battery-electric vehicles – is mostly uncertain as well. The scope of technology-specific discrimination should, therefore, be limited.

Technology openness in today's transport sector is limited. Various forms of market imperfections and policy failures (described in Box 1) bias the decision spaces for passenger cars, light utility trucks, and long-haul trucks. Hence, technology decisions in today's transport sector do not take into account all the relevant social costs and benefits – all the less so because the choices of drive systems, fuels, and infrastructure are closely interlaced.

Path dependencies restricting technology openness in the transport sector constitute a specific challenge for policy-makers. Today's technology selection is shaped significantly by the past investment decisions of private and public actors. These path dependencies prevent a sufficiently rapid transition to new technologies, though the strength of the dependencies varies from technology to technology. And today's decisions – e. g., to construct new infrastructures – usually come along with the creation of new path dependencies, too. Hence, errant policies, whether past or present, cast long shadows. Policy-makers must weigh this risk when devising technology-specific interventions.

In many cases, the regulation of technology choices in the transport sector aims to address other policy goals in addition to decarbonisation. These include energy efficiency, air quality, resource efficiency, energy system stability, and distributional or industry policy objectives. Different technologies can be variously suited for reaching these goals – and thus may warrant technology-specific interventions.

Strict technology neutrality does not make economic sense for reaching Germany's 2030 emission reduction targets in the transport sector. Technology-neutral policies cannot eliminate the current distortions in the decision spaces of the transport sector; on the contrary, they perpetuate them, resulting in inefficient technology neutrality. Policies for passenger cars, light commercial vehicles, and long-haul trucks need instead a certain amount of technology specificity. Technology-specific interventions most probably are required to increase technology openness in each of the decision spaces and address other policy goals in addition to decarbonisation. The knowledge for designing those interventions is at least partially already available. The economic reasons for technology-specific interventions vary from technology to technology and decision space to decision space.

Technology specificity does not necessarily mean the specification of a single technology. Even in an environment of technology-specific interventions a mix of different technologies can ensue and be reasonable. The regulatory framework can be designed in such a way that other technologies can, in principle, permeate the market alongside the government-promoted technology or technologies. Moreover, state interventions can explicitly consider technologies that today are still regarded as niche, such as fuel cells for passenger cars. Box 2 and Fig. 3 provide an overview of what are likely to be the most expedient areas of regulatory intervention in the decision spaces of passenger cars, light commercial vehicles, and long-haul trucks until 2030. Based on our analysis, a prioritization of individual technologies will probably be necessary in order to take into account different market potentials, different indication strengths for technology specificity, and budgetary limits for state expenditures. Nevertheless, to a limited extent regulatory measures should also be used to push the development of niche technologies in order to keep options open for reaching long-term climate targets

Box 2

Projected technology portfolio for passenger cars, light commercial vehicles, and long-haul trucks through 2030 along with economic indications for technology-specific interventions

In the passenger car segment, battery-electric drive trains will play a central role in the short to medium terms. Battery-electric drive trains are a market-ready technology that enables highly energy-efficient decarbonisation in the long term. Regulatory interventions should thus focus on reducing barriers for the use of battery-electric vehicles and ensure that plug-in hybrid vehicles use electricity for a high percentage of the miles they drive. Both technology-neutral and technology-specific interventions are indicated for reducing barriers for the use of battery-electric vehicles. The use of hydrogen fuel cells and synthetic fuels for internal combustion engines also enable the decarbonisation of passenger cars but given their current state of development probably represent only niche technologies in the time-frame until 2030. Neither is market-ready and both (especially synthetic fuels) exhibit high energy conversion losses. They should not be the focus of climate policies for passenger cars. Rather, they should be seen as potential options for the complete decarbonisation of the road transport sector in the long term. With regard to the further development of hydrogen technologies and synthetic fuels it is likely that positive spillover effects from utility trucks, air travel, and ship transport will occur. All in all, therefore, comprehensive technology-specific policies for these niche technologies appear less essential today.

In the segment of light commercial vehicles (trips with ranges of up to 150 km), battery-electric vehicles are expected to take hold in the medium term under current market policies and regulations already (e.g. air quality requirements, carbon limits for vehicle fleets). Even without comprehensive technology-specific interventions, battery-electric drive trains are expected to be the main technology for reducing carbon emissions in light commercial vehicles. The only area that may need technology-specific regulation is the charging infrastructure, which will further reduce barriers to the introduction of battery-electric vehicles.

In the long-haul truck segment, various drive trains and energy sources are likely to be deployed in parallel. The large amount of energy needed to transport heavy loads over long distances via roads poses a major challenge. Direct power from overhead catenary lines is the most energy-efficient option for powering trucks and delivers the lowest system costs for the main transport arteries. For routes outsides the main arteries, battery-electric and fuel cell drive trains are more affordable because they can cover a larger area for the same costs. Synthetic fuels can supplement the technology portfolio for certain applications (e.g. certain international routes).

A combination of these options is expected to represent the economic optimum. Accordingly, it is advisable to create policies that promote multiple technologies by reducing barriers to their introduction through suitable technology-neutral and technology-specific interventions, and enable synergies between those technologies (e.g. hybrid concepts). When planning energy supply infrastructure, the state must consider synergies between different electric drive systems. Promoting a broad range of technologies also diversifies the regulatory risks due to the considerable uncertainties about their further development. In the short term, a narrow focus on technologies may be more affordable, but would be risky and could be more expensive in the long run or jeopardize the achievement of Germany's climate targets. In this regard, the decision space of long-haul trucks is different from that of passenger cars, where the technologies positioned to make the largest contribution to Germany's climate targets in the short and medium terms appear to be foreseeable to a much greater extent.

Summary of key findings regarding technologies in the individual decision space — Figure 3

	Cars	**Local/regional freight transport**	**Long-distance freight transport**
Decision area	• Global mass market for battery electric vehicles already exists today • Change in mobility culture (multimodality, sharing, autonomous vehicles, etc.) → Range tends to decline in importance	• High cost pressure • Limited action radius • Predictability tends to be high • Requirements regarding air quality and noise emissions in urban areas • Limited supply of alternative drive technologies to date	• High cost pressure • Large driving distances • Heterogeneous usage profiles • Traffic concentrated on comparatively few routes • Alternative drives only available thus far as prototypes or in small series
Efficient technology mix in 2030	**Focus: Battery electric vehicles (Niche technologies: fuel cells, synthetic fuels)**	**Focus: Battery electric vehicles**	**ERS hybrid systems, fuels cells and battery**

Authors' depiction

after 2030. The targeted governmental singling out of individual technologies is only indicated for combustion engines powered by fossil fuels.

In most cases, some degree of technology neutrality is important. This is especially true for the details of technology design (e.g. the type of battery technology used for electric vehicles). Likewise, regulatory decisions predetermining the exact composition of the technology mix should be avoided. Explicit regulatory bans on specific technologies that can contribute to decarbonisation should only occur when there is a clear indication.

Climate policies for the transport sector should combine technology-specific with technology-neutral instruments

Technology-specific instruments must fit the economic indication. The reason for any technology-specific intervention – and, thus, the usefulness of individual instruments – can vary greatly from technology to technology. The mere existence of an economic indication for a technology-specific intervention does not justify an indiscriminate approach in using any technology-specific instrument. The goodness of fit between technology-specific instruments and their respective economic indication should be explicitly and clearly determined before their introduction. Moreover, efficient technology-specific instruments usually allow some leeway about the specifics of the technology options. This is mostly due to the fact the regulators usually face technological uncertainties and information limits. Generally, the approach to follow should be: **As much technology specificity as necessary, as much technology neutrality as possible.**

We have identified five main fields of climate policy action for road transport:

1. The market phase-out of fossil fuels ("exnovation")
2. The creation of complementary infrastructure for new low-carbon technologies
3. The development, production, and market penetration of new low-carbon technologies ("innovation")
4. Changes to travel behaviour and the reduction of road transport
5. A credible long-term political commitment to the decarbonisation of the road transport sector

An effective and efficient mix of instruments has to consider all five fields of action together.

1. **Instruments for "exnovation" are necessary to reduce the competitive advantages of fossil fuel engines and accelerate their phase-out, which is necessary to achieve the climate targets.** Without exnovation, the decarbonisation of the road transport sector will be impeded by strong path dependencies, lock-in effects, and prices that do not reflect environmental costs. Exnovation instruments can remain technology-neutral regarding new zero-carbon technologies. Every instrument mix for accelerating exnovation should include an ambitious carbon price, which penalises carbon emissions while allowing leeway for efficiently reaching carbon reduction goals. How the carbon price is implemented – be it a tax or part of an emissions trading system – is a secondary question. Additional fiscal incentives for vehicles purchases or when first registering a vehicle could be used if an ambitious carbon price proves politically unpopular. The additional incentives could, for instance, be implemented as part of a reformed vehicle tax centred on carbon emissions or as part of a bonus-malus system. To ensure climate targets are reached, production-side regulatory instruments such as strict fleet-wide emission limits for new cars could be introduced.
2. **The creation of a complementary infrastructure for the operation of new technologies must be promoted by the state, at least temporarily.** Since complementary infrastructures typically relate to specific technologies, a technology choice by the regulator is unavoidable. This is all the more so because budgetary restrictions prevent the state from supplying large-scale complementary infrastructures for all technologies in parallel. Box 2 provides criteria for technological foci that make sense in the decision spaces at the moment. The private operation of new complementary infrastructures should be possible without state funding as soon as a critical mass is reached. Nevertheless, a permanent regulation governing certain areas or tariffs may be necessary – such as for electric road systems for long-haul trucks.
3. **Instruments for innovation may be needed that support the dissemination of vehicles with low-carbon technologies to remedy competitive distortions.** It must be carefully assessed what barriers (...) can thereby be addressed in a sensible manner, especi-

ally if the exnovation of fossil fuel technologies and the expansion of new complementary infrastructures are already guaranteed by other instruments. Depending on the economic indication, the design can be more technology-neutral or technology-specific. Regulatory instruments such as negotiable quotas for zero-carbon vehicles can be very effective. The situation is similar for restricting tax privileges for company cars to low-carbon vehicles. Premiums for the purchase of vehicles with low-carbon drive systems offer a chance to overcome demand-side barriers (e.g. budgetary constraints). Yet the effectiveness of purchase premiums for climate policy is uncertain. The premium subsidies may not be fully passed through to car buyers, and there is the danger of windfall profits and rebound effects. It makes sense, therefore, to restrict the volume and duration of purchase premiums, to ensure their effectivity, and to design funding so that polluters pay (such as a bonus-malus regulation in the vehicle tax). Policies can be designed along the foci for technology policy identified in Box 2.

4. **An efficient climate policy for the road transport sector also requires instruments that incentivise changes to travel behaviour and the reduction of motorised road transport.** This holds true even if the state has successfully decarbonised the road transport sector. Road transport produces not only CO_2 emissions; it also has other negative environmental effects. It causes air pollution, consumes resources and takes up large amounts of space. Instruments to promote infrastructure expansion and innovation do not supply enough incentives for travel changes behaviour and the reduction of motorised road transport and they may even lead to rebound effects that harm the environment. One option for reducing vehicle kilometres without restricting mobility is the efficient organisation of the transport system through, say, bundling different forms of transport and improving multimodal services. The necessary incentives include sending appropriate price signals in the road transport sector. The design of the instrument must be geared to prevailing technologies. Under current conditions, a carbon price can incentivise changes to travel behaviour and the reduction of traffic volume. In a completely electrified mobility system, an electricity tax can send the appropriate signals. Such signals can also come from technology-neutral, distance-based road tolls.

5. **In any case, successful climate policy in motorised road transport requires a clear and credible long-term political commitment to sector transformation.** Without a credible political commitment to the aims, directions, and irreversibility of the transformation, private actors will not invest enough in new infrastructure and production factories. Possible means for creating trust among private actors are public investment in complementary infrastructure and the creation of a cross-party agreement on ambitious climate change mitigation. What is also helpful is an instrument mix that defines clear transport and environmental policy goals, broadly addresses all five fields of action for road transport climate policy, and is anchored at all political levels (European, national, local).

   Individual instruments cannot guarantee the efficient transformation of the road transport sector. An efficient decarbonisation policy must coherently address all five fields of policy action and must not restrict itself to the regulation of individual ones. This requires a coherent portfolio of instruments that combines more technology-neutral instruments with more technology-specific ones. Although a technology-neutral carbon price alone would create incentives for exnovation, for changes to travel behaviour, and for the reduction of traffic volume, it would not overcome all the barriers for establishing new technologies. As a result, some technologies may not catch on at a speed and degree that is economically expedient. The transformation of the road transport sector would last longer and would be more expensive for society, and political resistance would increase. Conversely, a strategy would also be problematic that relied solely on technology-specific instruments in innovation, such as purchase premiums. Without exnovation instruments and a fundamental political commitment, the effectiveness of such instruments would be doubtful. At the same time, unnecessarily high funding costs must be taken into account. Moreover, a policy based solely on funding would increase traffic volume. When designing the mix of instruments, we must consider the relationships and dependencies between the fields of action. If the state pursues a selective technology policy, it must be consistent over all fields. For instance, it must conceive of infrastructure funding and innovation funding concurrently.

The decarbonisation of the road transport sector is a fundamental and long-term transformation process. Accordingly, it makes sense to adjust policy instruments to each of its phases as they unfold over time. The role of transport policy instruments will change as the decarbonisation of the road transport sector progresses and technology develops. If decarbonisation is successful, exnovation instruments may be discontinued. Funding instruments to expand the complementary infrastructure and innovation are typically needed only temporarily until a critical mass is reached. State incentives for changing travel behaviour and reducing traffic volume must be modified as the mix of technology changes. At present, a carbon price can supply these incentives. As the transport system becomes more electrified, this task must be performed by other instruments, such as an electricity tax or a distance-based toll for vehicles. The transition to these instruments is also necessary so that a decarbonised road transport sector can contribute to financing road transport infrastructure and public budgets.

The specific design and integration of policy instruments determines the success of technology-specific climate policy in the transport sector

As a rule, new (technology-specific) instruments must be integrated into a suitable regulatory framework. Due to the complexity of the individual transport policy decision spaces, a mix of existing and new instruments is indispensable. When introducing new instruments, the government must consider the possibility of undesirable interactions with existing systems. Adjustments to the existing regulatory framework may be necessary; otherwise, the effectiveness, efficiency, and ultimate political feasibility of the instrument may come into doubt. Accordingly, carbon prices are very unlikely to be effective unless the state also eliminates climate-damaging subsidies.

Even technology-specific instruments that are advantageous in theory can fail to be effective and efficient in practice. What is decisive for an efficient and effective implementation is the specific design of the instruments and the existing regulatory setting. Conflicting targets, interrupted transmission of price signals, legal problems, information deficits, transaction costs, and regulatory capture can cause that otherwise suitable technology-specific approaches to fall behind others in practical comparison. And errant technology-specific interventions can create new biases that further restrict technology openness. It is crucial that the state constantly check and demonstrate that the politically negotiated design of technology-specific instruments fits the actual economic indication.

Lingering uncertainties about the effectivity and efficiency of transport policy instruments cannot be used as an excuse for inactivity. In view of climate urgency and the necessary long-term investment in the road transport sector, clear policy targets must now be set to initiate the decarbonisation of the transport sector. It is better to introduce a "second-best" decarbonisation policy for road transport than go without a clear policy position. The current policies for the 2030 Climate Action Plan must also be assessed in this light. (See Box 3.)

Box 3

Assessment of current climate policies of the German federal government

The German federal government's **2030 Climate Action Programme** presents a catalogue of measures to reach the transport sector targets laid out in Germany's 2050 Climate Action Plan and its 2019 climate law. Some of the measures have already been enacted; others still require additional specifications. Below we briefly assess whether Germany's current measures adequately take into account the expedient fields of action for climate policy we identify above.

Market phase-out of fossil fuels ("exnovation")
To accelerate the gradual phase-out of fossil fuels in the transport sector, the German government plans to introduce an emissions trading system for the fuels used in the transport and building sectors. Policy-makers originally planned a fixed price of 10 euros per tonne of CO_2. Over the course of subsequent negotiations with the Federal Council (Bundesrat), the carbon price was raised to 25 euros per tonne of CO_2. Moreover, the programme relies on the existing EU fleet-wide emission limits for new cars. It also plans on amending the existing truck toll system and vehicle tax to take greater account of carbon emissions. But the government has yet to specify the proposed measures and issue a timetable.

It is doubtful whether Germany's proposed and enacted instruments will produce enough exnovation for decarbonising the transport sector. An ambitious carbon starting price and a steeper subsequent price path for emissions trading would be particularly needed. If this is politically unfeasible, a carbon-based reform of the vehicle tax would become even more important. This reform may comprise the establishment of a consistent, revenue-neutral bonus-malus system that provides direct fiscal incentives at the time of purchase of a new vehicle. A clear penalty for carbon-intensive drive systems would create incentives for buying climate-friendly vehicles.

Moreover, an elimination of existing disincentives would help further motivate exnovation. Some examples of those disincentives are the questionable distinctions in the energy taxes, especially exceptions for diesel and company cars with conventional combustion engines.

The creation of complementary infrastructure for new low-carbon technologies
Germany's programme focuses on the expansion of the **charging infrastructure for battery-electric vehicles**, with a goal of reaching 1 million charging points by 2030. In addition to state funding for charging points, the programme also plans to reduce legal impediments to their erection, such as building and property laws. Moreover, the federal government plans to develop **concepts for expanding the fueling, charging, and overhead cable infrastructure** for road haulage.

The technology-specific focus on the promotion of charging points for battery-electric vehicles seems to make economic sense, at least for passenger vehicles. But state funding is only expedient if a critical mass of charging stations can be created so that it can then be expanded by the private sector. It is not yet clear whether this critical mass can be reached or will already be exceeded with the installation of 1 million charging points. At any rate, measures for providing the necessary complementary infrastructure for long-haul trucks require specification and implementation soon, so that the required emission reductions can be enabled for long-haul trucks. The climate action programme does not allow a concrete assessment on this score.

The development, production, and procurement of new low-carbon technologies (innovation)
The climate action programme provides **state-funded purchase premiums for electric cars and trucks** (battery-electric vehicles, fuel cell-powered vehicles, plug-in hybdrids) as the main instrument for promoting the market penetration with alternative propulsion technologies. For passenger cars, Germany wants to extend and increase existing purchase premiums, especially for vehicles costing less than 40,000 euros. Moreover, it plans to extend the tax privilege for battery-electric and plug-in hybrid company cars through 2030 and expand it for vehicles costing less than 40,000 euros. Supplemental measures include the support of the **research and development of fuel cells and electricity-based synthetic fuels and advanced biofuels**.

The effectiveness of these climate measures as a whole, however, is uncertain. There is the danger that the purchase subsidies for low-carbon vehicles won't be passed on to the buyers entirely and that windfall profits and rebound effects will occur. The effectiveness is particularly uncertain if no measures are enacted that disincentivise the use of drive technologies that consume fossil fuels.

In view of this uncertainty – and for the sake of preserving public budgets – it makes sense to deploy purchase premiums in a more focussed manner than planned. For instance, limiting purchase premiums to vehicles costing less than 40,000 euros would help stimulate demand in customer segments whose budgets are actually restricted. An effective means to increase market penetration would also be a tradeable (and budget-neutral) quota for emission-free vehicles.

Also, it is dubious whether the planned promotion of plug-in hybrids, especially as part of a company car tax exception, makes sense from a climate policy perspective. To the extent that hybrid vehicles are primarily powered by fossil fuels in practice, they do not provide a significant contribution to climate change mitigation. Specific support measures should only be granted, however, if and to the extent that the technologies can actually be expected to contribute to decarbonisation.

Notwithstanding a stronger focussing of funding instruments, the carbon-based taxation of fossil fuel vehicles will remain important for efficiency, effectivity, and financing.

Changes to travel behaviour and the reduction of road traffic volume
In reducing traffic volume generally, Germany's climate action programme relies on a variety of measures for **promoting other forms of mobility and making them more affordable and easier to use**. These include decreasing value-added tax for long-distance train travel, expanding and modernising and electrifying railway lines, and allocating more public funding for expanding public transit and bike paths. But it is doubtful whether the proposed measures will significantly contribute to changing travel behaviour and reducing traffic volume. For one, the emissions trading system is not ambitious enough to have much of an impact here. For

another, the effects of its proposed support measures are uncertain. For instance, efforts to increase the number of passengers may be restrained by short- and medium-term capacity bottlenecks in the train and public transit systems. And cuts to the value-added tax for train passengers may be retained by the railway company by means of future price increases.

In addition, Germany's action programme sets incentives that could even lead to a greater amount of traffic volume. Examples include increasing tax allowances for car commuters and the introduction of a mobility bonus. Moreover, the extension and further increase of tax privileges for company cars used for private purposes with alternative drive systems will tend to increase traffic. And the extended comprehensive privileges for plug-in hybrids can even lead to an increase of carbon emissions.

Germany needs additional measures to slow the continuing growth of traffic volume. Otherwise, the climate action package – which to date relies primarily on promoting alternative drive technologies – cannot guarantee an efficient and sustainable achievement of climate targets in the transport sector. At present, a much more ambitious carbon price or higher energy taxes could serve as an incentive to change travel behaviour and reduce traffic volume. In the medium term, a distance-based passenger car toll could fulfil this purpose and support a more efficient use of transport.

Additionally, in an increasingly electrified mobility system, the electricity tax can play a role in changing travel behaviour and reducing traffic volume. Likewise, it could help reverse the trend of using ever larger, heavier and powerful vehicles. With a view to the environmental burdens accruing in the upstream chain, even electric vehicles should consume as little energy as possible. Germany needs suitable instruments that encourage these outcomes.

Credible long-term political commitment
For the purposes of long-term political orientation, the German federal climate law sets greenhouse gas **reduction targets for each sector and year**. It plans to **monitor** adherence to these targets on a continual basis. If the yearly reduction targets are not reached, Germany plans to introduce immediate supplementary measures.

As a rule, setting specific regulatory sector targets is a welcome part of a credible long-term political commitment to decarbonisation. Failing to meet targets will cause considerable costs for the federal budget as part of the climate action directive. The directive governs the share of the burden in the European Union for reducing greenhouse gas emissions in sectors outside the European emissions trading system, which includes road transport.

If Germany fails to reach targets in the non-ETS area, it must purchase emission allowances from countries that exceed their reduction targets. On the level of individual sectors or departments, there are no explicit and effective penalties for when targets are not reached, which weakens the credibility of sector targets.

The widely held view that further measures for reaching goals need to follow Germany's climate action programme and the continued existence of contradictory signals (i.e. subsidies for transport that harms the climate) do not underpin the credibility of the political commitment, either.

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In partnership with key players in the field of politics, economics, science and civil society, Agora Verkehrswende aims to lay the necessary foundations for a comprehensive climate protection strategy for the German transport sector, with the ultimate goal of complete decarbonisation by 2050. For this purpose we elaborate the knowledge base of climate protection strategies and support their implementation.

This publication is available for download under this QR code.

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